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D-89522 Heidenheim (DE)(54) **METHOD AND APPARATUS FOR THIN FILM FORMATION, DEVICE, ELECTRO-MAGNETIC APPARATUS,
DATA RECORDING/REPRODUCTION APPARATUS, SIGNAL PROCESSOR, AND METHOD OF
PRODUCING MOLTEN CRYSTAL.**

(57) A method and an apparatus for forming a thin film on a substrate surface, wherein the thin film is formed while applying vibration to the substrate or its surface. In a device having a substrate and at least one layer of a thin film formed thereon, and in an electro-magnetic apparatus constituted by integrating such devices, the device and the electro-

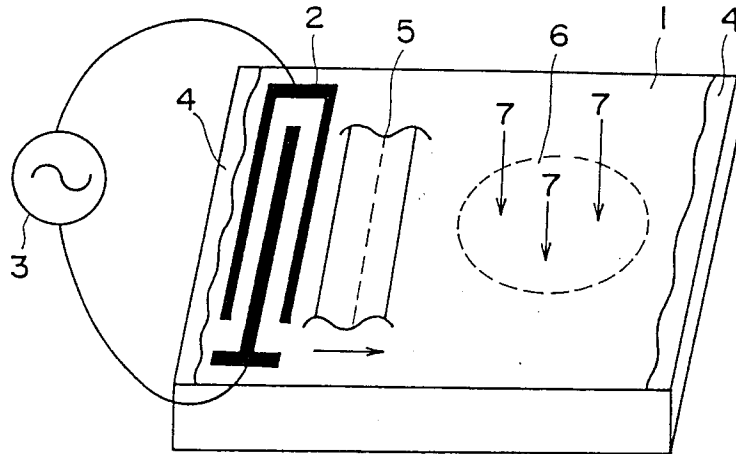
magnetic apparatus are characterized in that at least one layer of the thin film is a thin film formed by applying vibration to the substrate surface. In a data recording/reproduction apparatus, a data recording medium apparatus is one wherein the recording layer is a thin film formed by applying vibration to a substrate surface, and a recording head is one

EP 0 590 148 A1

wherein the core part is a thin film formed by applying vibration to the substrate surface. A data processor for inputting, recording, processing and outputting data is characterized in that a recording section uses a data storage medium apparatus whose recording layer is a thin film formed by applying vibration to the substrate surface and a processing

section uses a semiconductor device having a thin film formed by applying vibration to the substrate surface. A method of producing a molten crystal by cooling a melt from a high temperature is characterized in that crystal is grown while applying vibration thereto.

F i g . 1



A method and an apparatus for preparing thin films, a device, an electronic and magnet apparatus, an information recording and reproducing apparatus, an information processing apparatus and a method for preparing crystal from the melt.

TECHNICAL FIELD

The present invention relates to a method and an apparatus for preparing thin films, a device, an electronic and magnetic apparatus, an information recording and reproducing apparatus, an information processing apparatus and a method for preparing crystal from the melt.

BACKGROUND OF THE INVENTION

In recent years, various techniques have been proposed with reference to methods for forming thin films and for preparing crystal. This film forming methods such as evaporation, sputtering, CVD and the like are described in "Thin film Handbook" ed. by the Japan Society for the Promotion of Science (Ohm), and as to single crystal forming method, for example, Czochralski method and zone melting method are well known, as described in "Crystal Technology Handbook" ed. by the Compilation Committee of kessho-kogaku handbook (Kyoritu Shuppan).

The prior art techniques mentioned above are effective for the control of crystal growth, but no effect of mechanical oscillation the crystal growth surface has been taken into consideration.

The purpose of the present invention is to provide a thin film forming method and a thin film forming apparatus which take advantage of the effect of mechanical oscillation on crystal growth at initial stage of crystal growth.

The another purpose of the present invention is to provide a device having a thin film prepared by taking advantage of the effect of mechanical oscillation on crystal growth at initial stage of crystal growth.

DISCLOSURE OF THE INVENTION

The first aim of the present invention is to provide a method for forming a thin film on the surface of a substrate, wherein the thin film is formed as the substrate or the surface of the substrate is being excited.

The second aim of the present invention is to provide a thin film forming apparatus for forming a thin film on the surface of the substrate, wherein exciting means for exciting the surface of the substrate by surface acoustic wave (SAW) is installed.

The third aim of the present invention is to provide a device comprising a substrate and a thin

film with at least one layer prepared thereon, wherein at least one layer of the thin films is prepared as the surface of the substrate is being excited.

The fourth aim of the present invention is to provide an electronic and magnetic apparatus comprising a device having at least a substrate and a thin film with at least one layer prepared thereon, wherein at least one layer of the the thin film is prepared as the surface of the substrate is being excited.

The fifth aim of the present invention is to provide an information recording and reproducing apparatus for recording and reproducing information comprising an information memory medium device with a thin film prepared as the surface of the substrate is being excited and a recording head whose core part has a thin film prepared as the surface of the substrate is being excited.

The sixth aim of the present invention is to provide an information processing apparatus for in use in input, record process and output of information, comprising a recording part having an information memory medium device wherein a recording layer is a thin film prepared as the surface of the substrate is being excited and a processing part with semiconductor device having a thin film prepared as the surface of the substrate is being excited.

The seventh aim of the present invention is to provide a crystal forming method for growing crystal by cooling down the melt from high temperature, wherein the crystal is prepared as being excited.

OPERATION

The present inventor has found out that the structure of crystal grain is changed by the mechanical oscillation put on the crystal growing surface at initial stage of crystal growth. According to this finding, it becomes possible to control crystal growth by oscillation as mentioned above, then to form various thin films having excellent characteristics, and consequently to construct various devices and electronic and magnetic apparatus with high reliability. It is also possible to provide an information recording and reproducing apparatus with low error rate and an information processing device with high processing rate.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a prospective view illustrating the 1st embodiment of the invention.

Fig. 2 is a fragmentary sectional view of a film forming apparatus in accordance with the embodiment 1.

Fig. 3 is a plan view of parts in accordance with the embodiment 1.

Fig. 4 is a graph showing the relation between applied voltage and the rise in substrate temperature in accordance with the embodiment 1.

Fig. 5 is a graph showing the anisotropic magnetic field H_k as a function of applied voltage, excited amplitude, or substrate temperature in accordance with the embodiment 1.

Fig. 6 is a graph showing the structure factor as a function of applied voltage, excited amplitude, or substrate temperature in accordance with the embodiment 1.

Fig. 7 is a graph showing the coercive force as a function of applied voltage, excited amplitude, or substrate temperature in accordance with the embodiment 1.

Fig. 8 is a SEM image of the film prepared at room temperature (without excitation) in accordance with embodiment 1.

Fig. 9 is a SEM image of the film prepared at applied voltage of 8V in accordance with embodiment 1.

Fig. 10 is a SEM image of the film prepared at applied voltage of 9V in accordance with embodiment 1.

Fig. 11 is a sectional view of the crystal forming furnace in accordance with embodiments 2 and 3.

Fig. 12 is a schematic diagram showing a method of SAW excitation in accordance with the embodiment 4.

Fig. 13 is a schematic diagram showing a method of SAW excitation in accordance with the embodiment 5.

Fig. 14 is a schematic diagram showing a method of SAW excitation in accordance with the embodiment 6.

Fig. 15 is a plan view in accordance with embodiment 7.

Fig. 16 is a sectional view of a thin film magnetic head in accordance with the embodiment 8.

Fig. 17 is a schematic diagram showing a method for constructing a magnetic disk in accordance with the embodiment 9.

Fig. 18 is a schematic diagram showing a part of the interconnecting pattern in accordance with the embodiment 10.

Fig. 19 is a schematic diagram showing an prior art MBE method.

Fig. 20 is a schematic diagram showing a method of forming superlattice thin film in accordance with the embodiment 11.

Fig. 21 is a schematic diagram showing a method for forming a Josephson device in accordance with the embodiment 11.

Fig. 22 is a schematic diagram showing a magnetic recording and reproducing apparatus in

accordance with the embodiment 13.

Fig. 23 is a fragmentary sectional view of an integrated circuit in accordance with the embodiment 14.

Fig. 24 is a block diagram showing an electronic computer system in accordance with the embodiment 15.

A list of parts and numerals shown in the figures is as follows:

1,20,23;	Substrate,
2,19,43;	Interdigital electrode,
5;	Surface acoustic wave (SAW),
6,35;	Thin film formed area,
7;	Flow of particles,
15 17;	Ultrasonic oscillator,
24;	Wedge-shaped oscillator,
25;	Reflector,
26,27;	Group of interdigital electrodes,
33;	Lower core,
20 34;	Upper core,
36,44;	Magnetic disk,
37,38;	Interconnector,
39;	Interlayer insulator,
41;	Atom,
25 42;	Superconductor thin film,
51;	Source electrode or drain electrode,
52;	Gate electrode,

DESCRIPTION OF THE PREFERRED EMBODIMENTS

(Embodiment 1)

The first embodiment of the present invention will be described below, referring to Figures 1 - 10.

In this embodiment, a 128° Y-K cut LiNbO_3 crystal 1 was used as a substrate and interdigital electrodes 2 were formed on the substrate.

Surface acoustic wave was generated by applying high frequency electric field (45 MHz) to both ends of the interdigital electrodes through a signal source 3.

Acoustic absorbers 4 were coated near the edges of substrate to reduce the reflection of SAW. A mask 9 restricting flow of the particles 7 was mounted on the substrate and then thin film was prepared on an area 6 by D.C sputtering with a Permalloy target having composition of 83 wt% Ni, 15.7 %Fe, 1 %Mo and 0.3 % others.

Fig. 2 shows a fragmentary sectional view of a substrate holder of a sputtering apparatus used in this embodiment. The substrate 1 was fixed on a holder body 10 by a substrate retainer 8 and then a mask was mounted on the retainer 8. High frequency signal was supplied to the interdigital electrodes 2 from electric source terminal 11 through conductive wire 12. The vacuum of a film forming chamber was maintained with an o-ring seal 13.

Fig. 3 shows enlarged views of the holder body 10, the retainer 8 and the mask 9.

Most energy of SAW generated through electrode 2 is absorbed by acoustic absorbers 4 and converted to heat. Therefore, the temperature of the substrate will rise with the increase in voltage of the signal source 3. Fig. 4 shows the relation between the applied voltage and the rise in substrate temperature. The temperature was obtained from the measurement on deviation of passing frequency characteristics from the pole performed by constructing a few pair of interdigital electrodes on the substrate. The small number of the pair reduces the effect on SAW.

The thin film was prepared at pressure of 6 mtorr and at deposition rate of 30 nm/min. Fig. 5 represents anisotropic magnetic field H_k as a function of applied voltage through signal source, temperature of the substrate, or amplitude of SAW. The temperature was obtained from the relationship shown in Fig. 4, and the amplitude from conductance of the device and aperture. In the case of no SAW excitation, the substrate was heated by a heater to the same temperature as that in the case of excitation. In Fig. 5, there is a remarkable difference of anisotropic magnetic field H_k between without excitation and with excitation at applied voltage of about 8V, which corresponds to 15-30 A in amplitude of excitation. Namely, it is apparent from the figure that direction of easy magnetization is changed by excitation.

Similarly, Fig. 6 shows the structure factor S as a function of applied voltage, temperature of the substrate or amplitude of SAW. The structure factor S was obtained by the measurement of dynamic differential susceptibility. The measurement method is described in detail in "The Transaction of the Institute of Electronics, Information and Communication Engineers; Transaction on Magnetic Recording MR89- (1989)."

Fig 7 shows the saturation magnetization H_c as a function of applied voltage, temperature of the substrate, excitation amplitude. In Figures 6 and 7, drastic differences are observed around 8 V between curves. It can be presumed from these results that the crystal grain prepared at applied voltage of 8V is small.

Next, SEM images were observed. Fig. 8 shows a SEM image of a film prepared without excitation at room temperature. This film is made of relatively large crystal grain with clear grain boundary. Fig. 9 is a SEM image of a film prepared at applied voltage of 8V, showing that the film is made of small grains with obscure boundary and smooth surface. Fig. 10 is a SEM image of a film prepared at applied voltage of 9V. The film has relatively large crystal grains with clear boundary.

Thus, it was found in this embodiment that exciting the crystal growth surface makes crystal grain small and the crystal surface smooth.

(Embodiment 2)

Fig. 11 is a sectional view of a Czochralski type single crystal forming furnace in accordance with the 2nd embodiment. A material is placed in a crucible 18 and heated by a heater 15. The melt of the material is in contact with a single crystal 16. An ultrasonic oscillator 17 is fixed to the bottom of the crucible 18. The mechanical oscillation generated by an ultrasonic oscillator 17 reaches the crystal growth surface and causes the smoothness of crystal growth plane. As a result, a high quality single crystal can be formed. The reason is not clear yet why the quality of the crystal is improved by oscillation, but it may be attributed to the increase in collision probability between atoms or molecules.

According to the embodiment 2, it becomes possible to form a single crystal with high quality and high uniformity. In other words, contrary to a prior art single crystal pulling method wherein it has been thought to be important to keep solid-liquid interface (i.e., interface between a seed crystal and melt) as stationary as possible in order to prepare a high quality single crystal, in this invention, homogeneous high quality single crystal could be prepared by oscillating the interface.

(Embodiment 3)

The same apparatus as shown in the embodiment 2 was used. In this embodiment, a material contains a second element (and others) more than solid solubility limit. Though, in general, it is thought to be difficult to mix the element more than solubility limit, it becomes possible by using the apparatus of this embodiment to produce composite containing the second element homogeneously. Similar effect can be expected in the case other than single crystal, i.e., in the case that no seed crystal is used. For example, it is possible to homogeneously introduce the second element and the third element into the thin film deposited from vapor phase without segregation.

(Embodiment 4)

The fourth embodiment is explained by referring to Fig. 12. This embodiment relates to a method for exciting surface acoustic wave. As mentioned in the first embodiment, interdigital electrodes are constructed on the substrate to generate SAW. Therefore, interdigital electrodes must be constructed on every substrate and connected to

external electrodes, resulting in low productivity. In this embodiment, a piezoelectric substrate 22 with interdigital electrodes 19 was pressed by external force 21 onto a substrate 20 and then SAW 5 was excited. A thin film is prepared by flow of particles on the substrate 20 which is being excited by SAW.

Thus, this embodiment can be preferably used in mass production because it is unnecessary to construct interdigital electrodes on every substrate.

(Embodiment 5)

In the first embodiment, the substrate is required to be piezoelectric. In the fourth embodiment, efficiency of excitation is low though SAW can be generated on a non-piezoelectric substrate. This embodiment shown in Fig. 13 provides a method to solve these problems. A oscillator is attached to the surface of a non-piezoelectric substrate 23. The mechanical oscillation excited by signal source 3 propagates as SAW. A thin film is formed on the substrate under oscillation by flow of particles 7 as mentioned above.

By using this embodiment various types of substrates can be used because no piezoelectric substrates are required.

(Embodiment 6)

Fig. 14 shows the embodiment 6. Reflectors 25 are prepared on both sides of interdigital electrodes 2 such that stationary wave is generated. Therefore, node and loop appear in SAW and one-dimensional alternating pattern of large and small crystal grains is formed in an area 6. And since the energy of SAW is confined between the reflectors 25, larger amplitude of excitation can be generated with less voltage. Furthermore, acoustic absorbers become unnecessary by making reflection coefficient of reflector 25 large. This means that the rise in substrate temperature is suppressed because of decrease in energy to be converted to heat. The high reflection coefficient is attained by increasing the number of lines of reflector.

According to this embodiment, the formation of one-dimensional pattern of thin film becomes possible with preventing the substrate temperature from rising. This means that the degree of freedom in preparing thin films increases.

(Embodiment 7)

The seventh embodiment is explained by referring to Fig. 15. The formation of one-dimensional pattern was carried out in the embodiment 6. This embodiment makes the formation of two-dimensional pattern possible. Two groups of a plural of

interdigital electrodes 26 and 27 are constructed in the directions of Y axis and X axis in order to two-dimensionally control the quality of a thin film. In other words, the amplitudes of SAW generated by interdigital electrodes 26 and 27 are adjusted 10 -30 A, each amplitude being adjusted to the value not more than 15 A. Furthermore, by scanning each excitation, it is possible to control crystal morphology in any case. In the case that only one group of electrodes is constructed, the one-dimensional control of crystal morphology can be attained as mentioned in the embodiment 6.

An mentioned above, two-dimensional control of crystal morphology becomes possible. Thus, this method is preferably used for formation of two-dimensional devices such as integrated circuit.

(Embodiment 8)

The eighth embodiment is explained by referring to Fig. 16. Fig. 16 shows a sectional view of a thin film head prepared by this embodiment.

At first, a lower core 33 is prepared as a substrate is being excited by SAW. The grain size of the film thus prepared was so fine that the permeability of the film was so high. Then, after a gap member 31, a coil 29 and an insulator 30 are formed, an upper core 31 is prepared under the excitation by SAW as well as the lower core 33 to make the permeability of the core higher. Finally, a passivation film 32 is prepared and then diced to the head by a dicing apparatus.

This embodiment make it possible to produce a high permeability thin film head with high efficiency of recording and reproducing characteristics.

(Embodiment 9)

The embodiment 9 is explained by referring to Fig. 17 illustrating a preparing method of a hard magnetic disk as a magnetic memory medium device. Interdigital electrodes 2 and acoustic absorbers 4 are prepared on a piezoelectric substrate 1. A thin film of hard material is prepared on the area 35 as the substrate is being excited by SAW. By this method, the preparation of hard material with fine crystal grain becomes possible and therefore a thin film with short coherent length can be prepared. Next, the magnetic disk is constructed by e.g., an ultrasonic fabrication.

Thus, it becomes possible by this embodiment to construct a magnetic disk with short coherent length, i.e., high recording density.

(Embodiment 10)

The tenth embodiment is explained by referring to Fig. 18 which illustrates a method to prepare interconnector pattern of integrated circuit. In the figure, only primary portion is shown. As well as in the embodiment 1, interdigital electrodes 2 and acoustic absorbers 4 are formed on a piezo-electric substrate 1, and then lower interconnector 37, interlayer insulator 39 and upper interconnector 38 are prepared on the substrate excited by SAW. By the excitation of SAW, the crystal grain of the film is so fine that the interconnector has high resistance to migration and high bonding strength, and that the insulator has high dielectric breakdown strength.

Thus, it becomes possible by this embodiment that reliable interconnectors are prepared for in use of integrated circuit.

(Embodiment 11)

The 11th embodiment of the invention is explained by referring to Figures 19 and 20.

Fig. 19 shows a thin film forming process by a prior art MBE method. In the prior art method, it is difficult to form superlattice, especially of metal. A flow of the evaporated atoms 40 reached a substrate and, as shown in the figure, every atomic layer is composed of both atoms 41 (a black and a white circles mean A atom and B atom, respectively); for example, the atom A enters into both the 2nd and 3rd atomic layer. Fig. 20 shows a method to prepare superlattice of the present invention. A thin film is prepared as the substrate is being excited by SAW as mentioned above, resulting in the formation of superlattice with high quality as a result of increase in the smoothness of the surface of every layer.

Thus, it is possible by this embodiment to prepare superlattice which has been commonly difficult to prepare by the prior art.

(Embodiment 12)

The 12th embodiment of the invention is explained by referring to Figure 21.

Fig. 21 shows a superconductor thin film prepared by the present invention. As well as in the embodiment 1, interdigital electrodes 43 and acoustic absorbers 4 are formed on a piezoelectric substrate 1, and then a superconductor thin film 42 is prepared on the substrate excited by SAW. Interdigital electrodes 43 are prepared in arc shape so that SAW can be focused on a point where the thin film with fine crystal grain and short coherent length can be prepared. Therefore, since superconductivity is weakened, a Josephson bonding can be

easily constructed there.

Thus, it is possible by this embodiment to reproduce a Josephson bonding relatively easily and reliably.

(Embodiment 13)

The 13th embodiment of the invention is explained by referring to Figure 22 which illustrates a magnetic recording and reproducing apparatus having a hard magnetic disk of the present invention. In this embodiment, an external memory unit 47 used for controlling instruments is constructed in which a controller 45 controls the movement of the magnetic disk 44 prepared by the embodiment 9 and the thin film head 46 prepared by the embodiment 8.

Thus, it becomes possible to construct the external memory unit with low error rate and large recording capacity.

(Embodiment 14)

The 14th embodiment of the invention is explained by referring to Fig. 23 which illustrates a fragmentary sectional view of a part of integrated circuit prepared by the invention. The figure shows an MOSFET. A SiO_2 film 50 and a conductive film 48 are formed on the front surface and on the back surface of a p-type silicon substrate 49, respectively. Then, in the same manner as the embodiment 10, source and drain electrodes 51, gate electrode 52, interconnector and interlayer insulator are formed as the substrate is being excited by SAW, producing the devices having high resistance to migration.

Thus, it becomes possible by this embodiment to construct the integrated circuit with high reliability and long lifetime.

(Embodiment 15)

The 15th embodiment of the invention is explained by referring to Fig. 24 which illustrates a block diagram of a computer system of the present invention.

Information data inputted through a key board and other input units are sent to and stored in a memory unit under the control of a controller. The information data stored in the memory unit are processed by an arithmetic unit and the results are stored in the memory unit under the control of the controller. Then, the results are outputted through an output unit. In the figure, solid lines mean flow of information data and the broken line the control. Here, the magnetic disk apparatus of the embodiment 13 and the integrated circuit of the embodiment 14 are used as a memory unit and an

arithmetic unit, respectively. By using these apparatus, high reliability and large memory capacity can be attained.

Thus, it is possible to provide an information processing apparatus with high reliability and large memory capacity.

APPLICATION TO INDUSTRIES

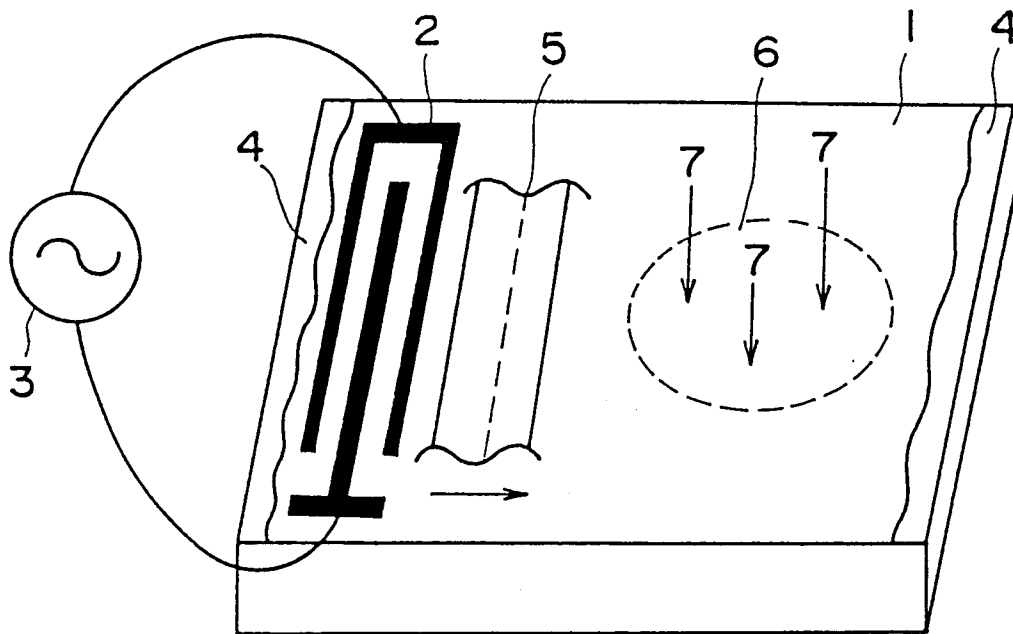
As mentioned above, the present invention make it possible to control the crystal growth of thin films and bulk materials and therefore to manufacture various types of materials with high quality. Consequently, high reliability, high efficiency and large capacity of the apparatus can be attained.

Claims

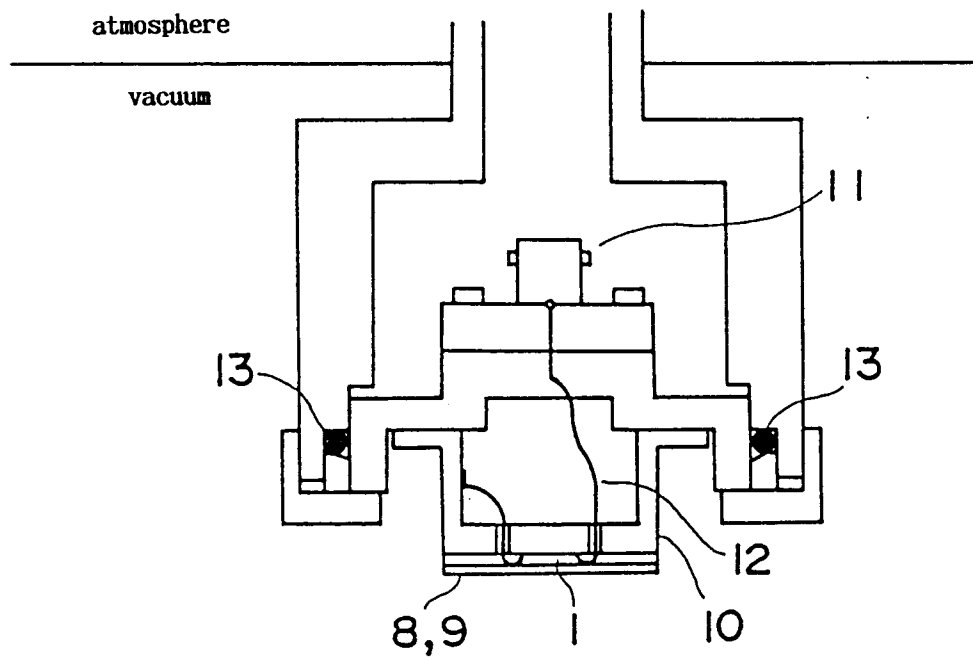
1. A thin film preparing method for preparing a thin film on the surface of a substrate, wherein said thin film is prepared as said substrate or said surface of said substrate is being excited.
2. A thin film preparing method according to claim 1, wherein said thin film is prepared by sputtering, evaporation, or CVD.
3. A thin film preparing method according to either claim 1 or 2, wherein said surface of said substrate is excited by surface acoustic wave.
4. A thin film preparing method according to claim 3, wherein amplitude of the surface acoustic wave excitation is a range of 1.5 through 3.0 nm.
5. A thin film preparing method according to one of claims 1 through 4, wherein said substrate is piezoelectric.
6. A thin film preparing method according to one of claims 3 through 5, wherein said surface acoustic wave is stationary wave.
7. A thin film preparing apparatus for preparing a thin film on the surface of a substrate comprising an exciting means for exciting the surface of the substrate by surface acoustic wave.
8. A thin film preparing apparatus according to claim 7, wherein said exciting means comprises an interdigital electrode and a means for applying voltage to said interdigital electrode.
9. A thin film preparing apparatus according to claim 8, wherein said interdigital electrode is fixed on said substrate.
10. A thin film preparing apparatus according to claim 8, wherein said interdigital electrode is formed on a piezoelectric member and said piezoelectric member can be in contact with said substrate.
11. A thin film preparing apparatus according to one of claims 8 through 10, wherein said interdigital electrode is formed in arc shape.
12. A thin film preparing apparatus according to claim 7, wherein said exciting means is a wedge-shaped oscillator.
13. A thin film preparing apparatus according to claim 12, wherein said substrate is non-piezoelectric.
14. A thin film preparing apparatus according to one of claims 7 through 13, wherein a plural of said exciting means are provided.
15. A thin film preparing apparatus according to claim 14, wherein a plural of said exciting means are disposed such that the substrate can be excited two-dimensionally.
16. A device comprising a substrate and a thin film with at least one layer prepared thereon, wherein at least one layer of said thin film is prepared as the surface of said substrate is being excited.
17. A device according to claim 16, wherein said thin film is soft magnetic.
18. A device according to claim 16, wherein said thin film is hard magnetic.
19. A device according to claim 16, wherein said thin film is metal or metal alloy.
20. A device according to claim 16, wherein said thin film is insulator.
21. A device according to claim 16, wherein said thin film is superlattice.
22. A device according to claim 16, wherein said thin film is superconductor.
23. An electronic and magnetic apparatus constructed by integrating a device comprising a substrate and a thin film with at least one layer prepared thereon, wherein at least one layer of said thin film is prepared as the surface of said substrate is being excited.

24. An electronic and magnetic apparatus according to claim 23, wherein said apparatus is a semiconductor device.
25. An electronic and magnetic apparatus according to claim 24, wherein said semiconductor device is MOSFET and gate insulator and interconnector thereof are prepared as the surface of said substrate is being excited. 5
26. An electronic and magnetic apparatus according to claim 24, wherein said apparatus is an information memory medium device and a recording layer thereof is prepared as the surface of said substrate is being excited. 10
27. An electronic and magnetic apparatus according to claim 24, wherein said apparatus is a recording head for recording information onto and reproducing information from an information memory medium device, wherein core of said recording head is prepared as the surface of said substrate is being excited. 15
28. An information recording and reproducing apparatus comprising the information memory medium device defined in claim 26 and the recording head defined in claim 27. 20
29. An information processing apparatus for use in input, record, process and output of information comprising a recording portion having the information memory medium device defined in claim 26 and a processing portion having the semiconductor device defined in claim 24. 25
30. A crystal preparing method for preparing crystal by cooling the melt at high temperature, wherein said crystal is prepared as being excited. 30
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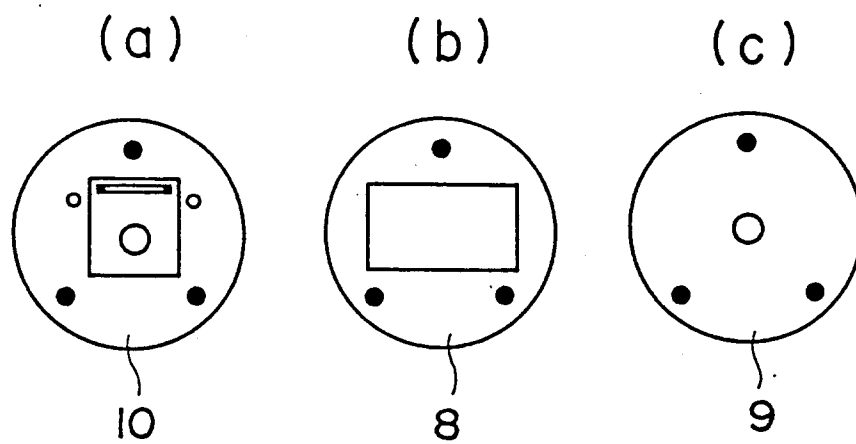
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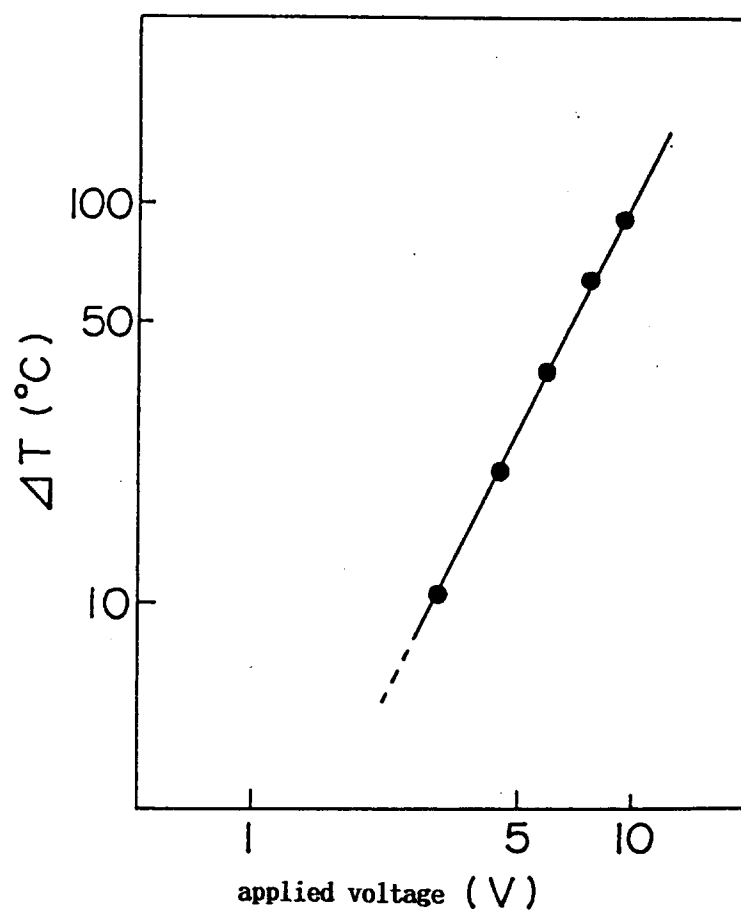
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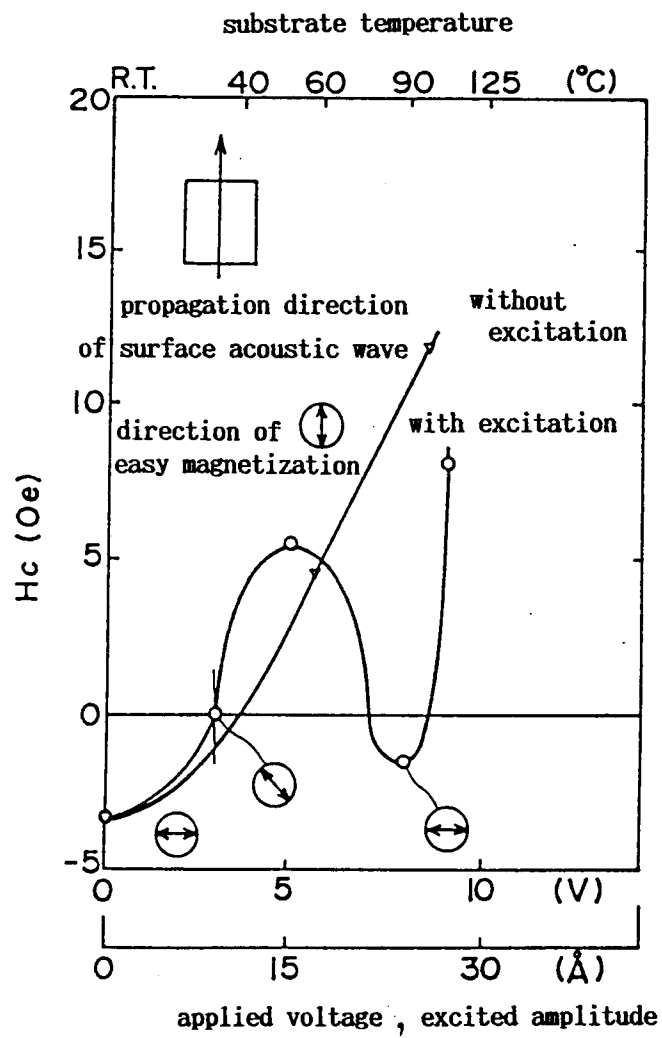
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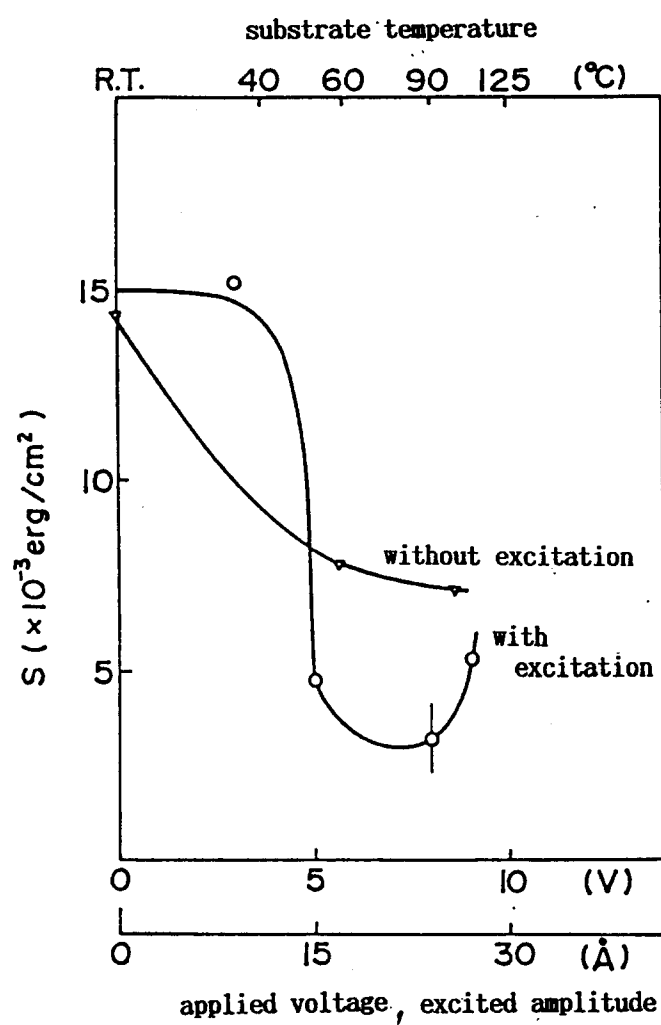
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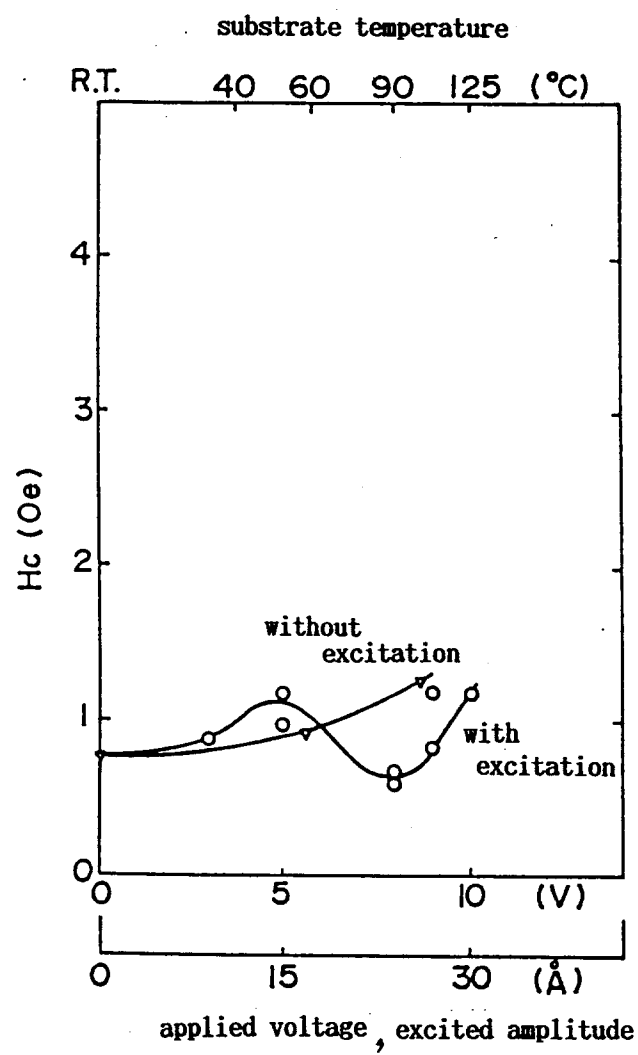
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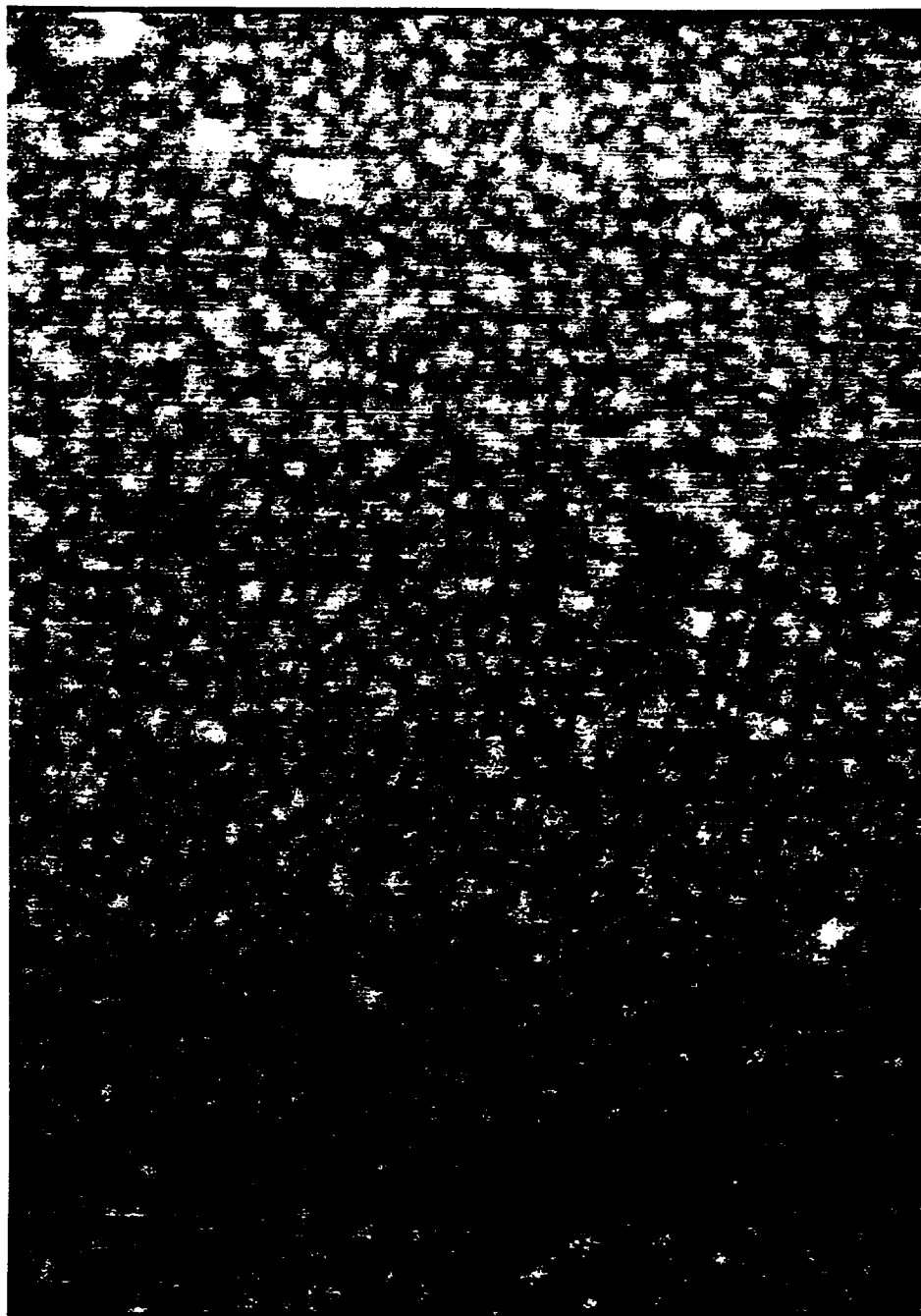
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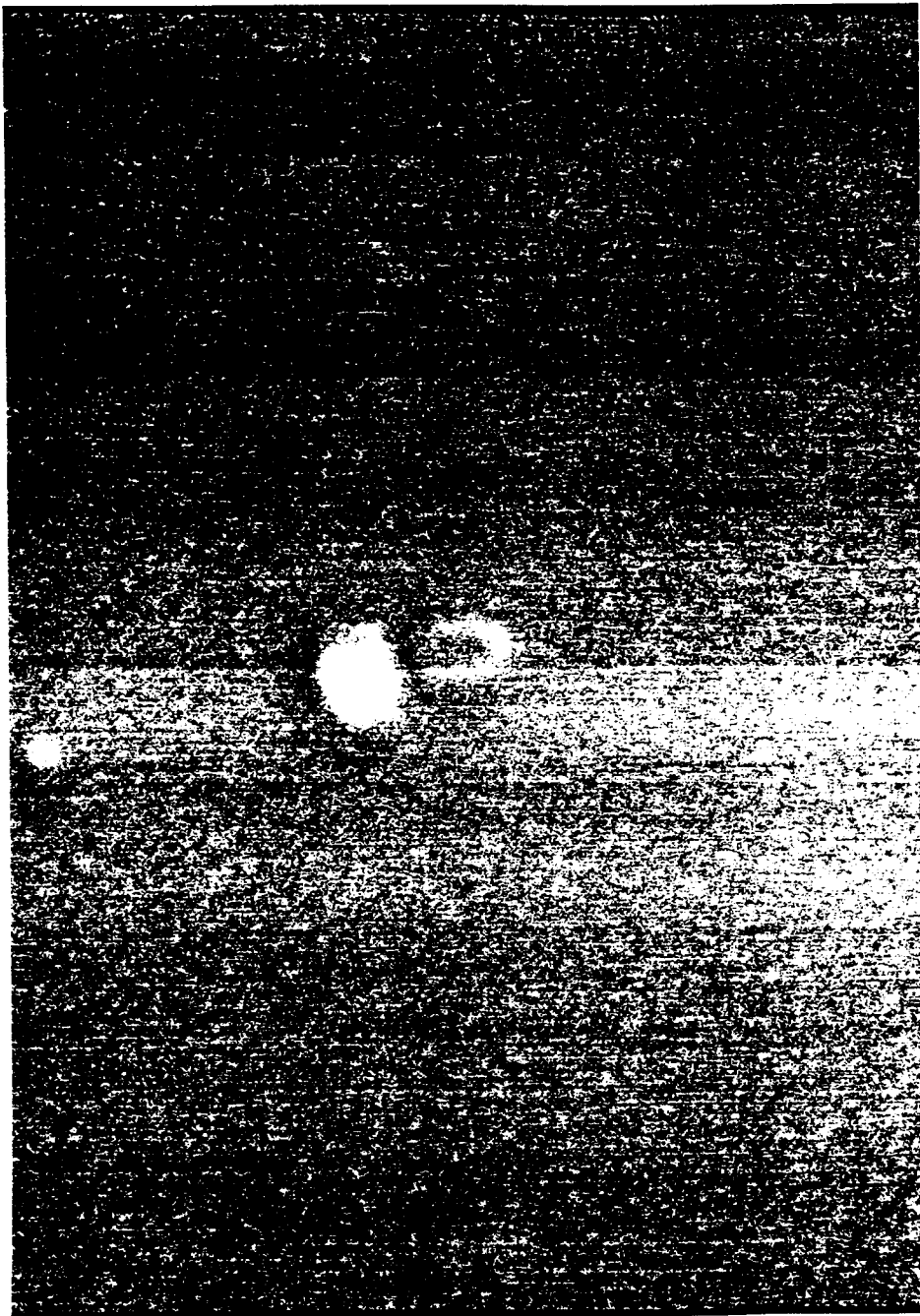
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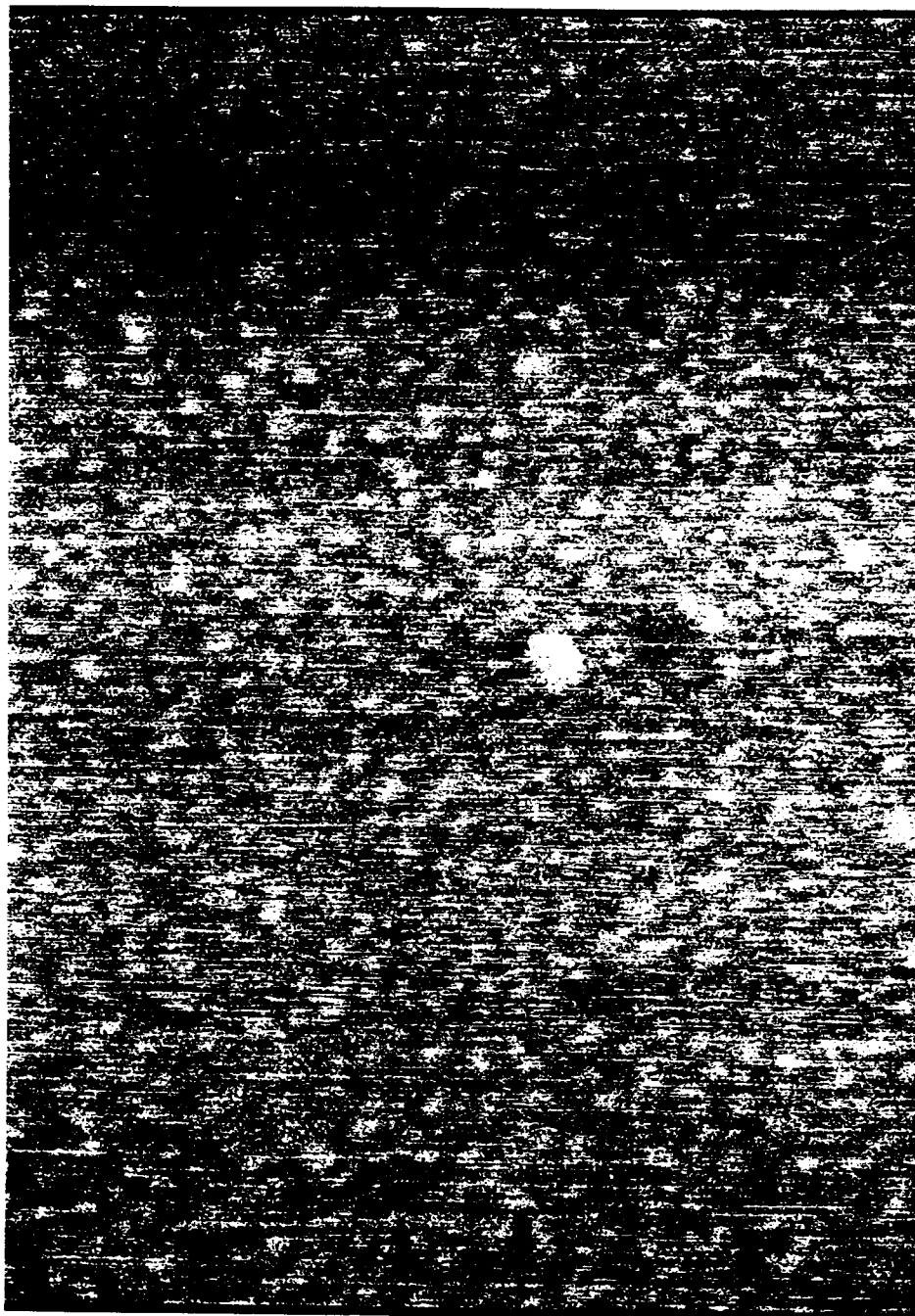
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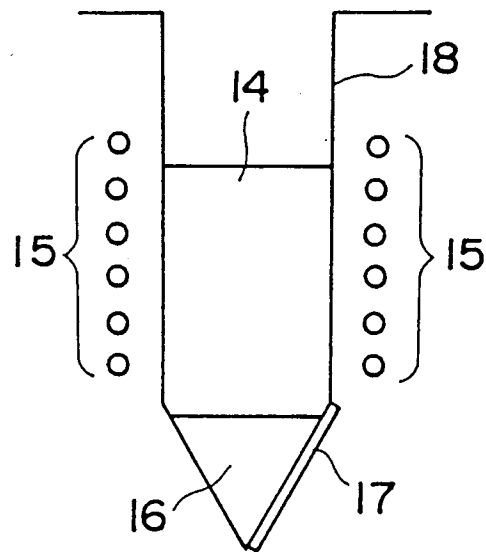
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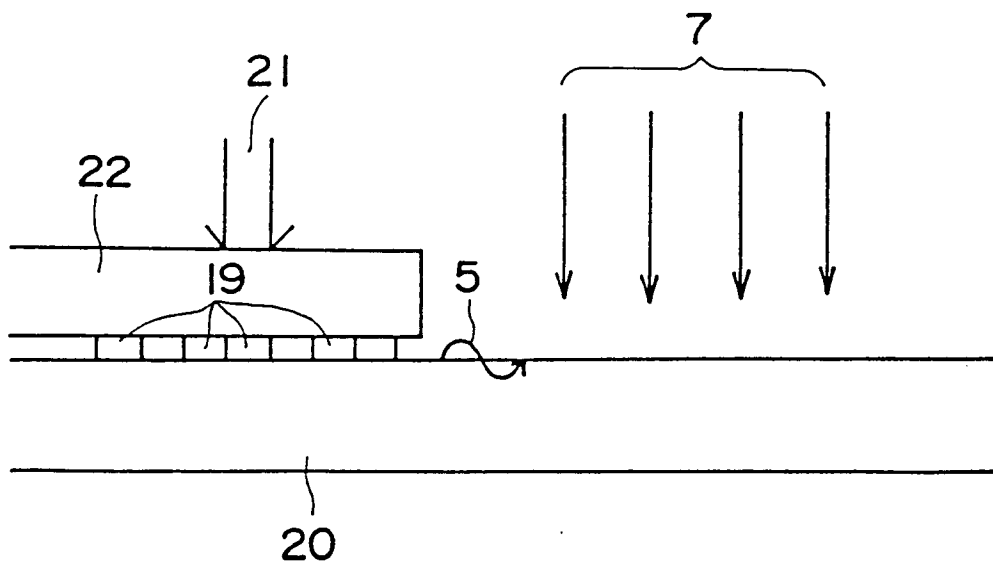
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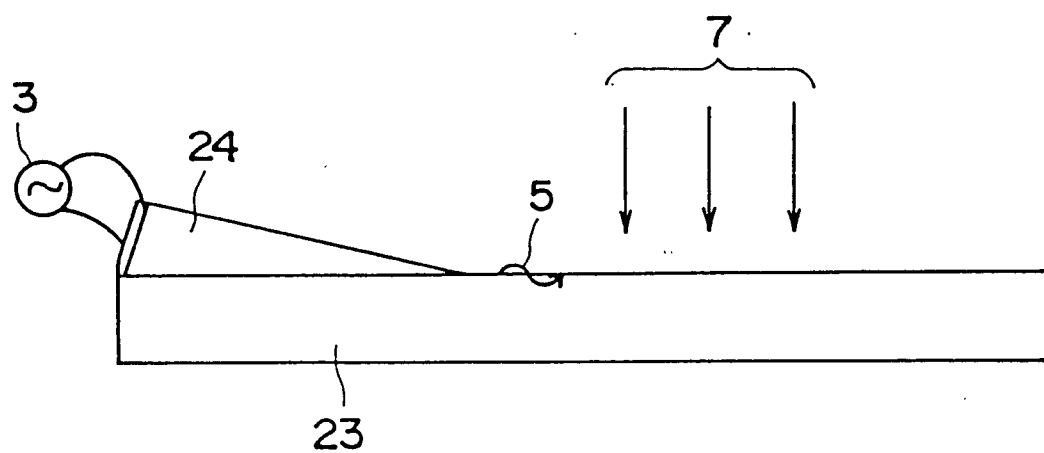
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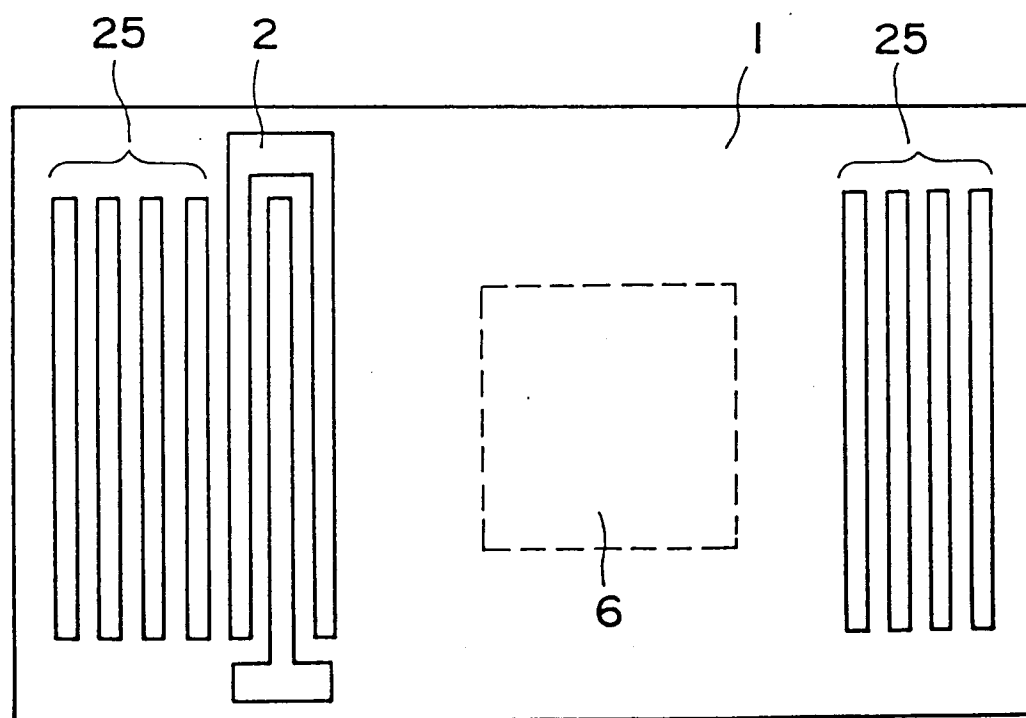
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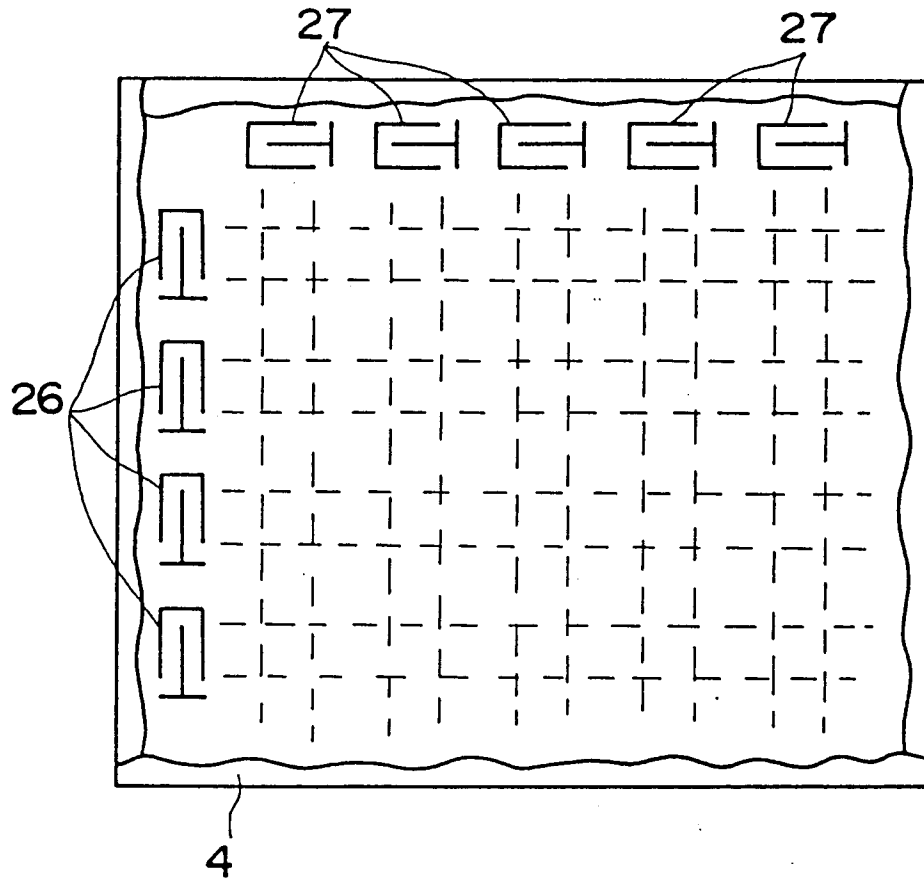
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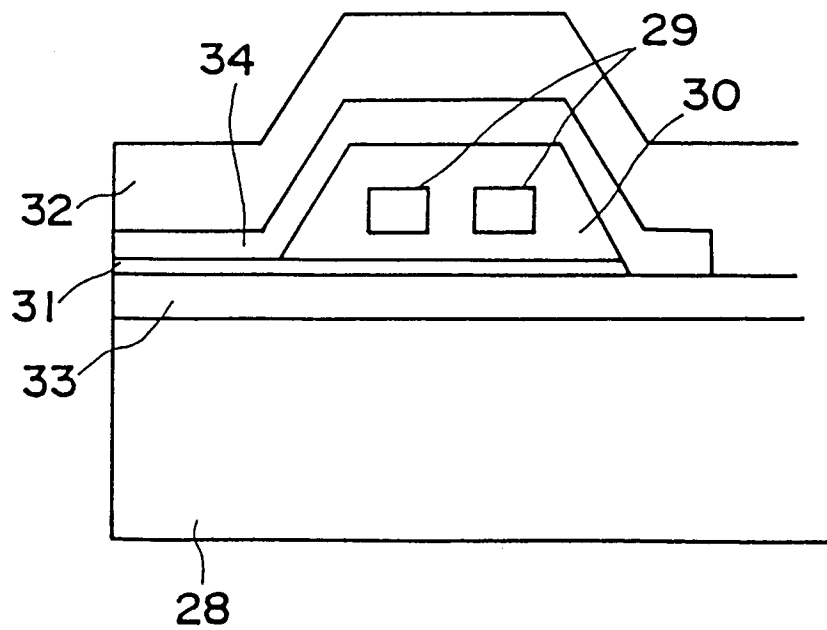
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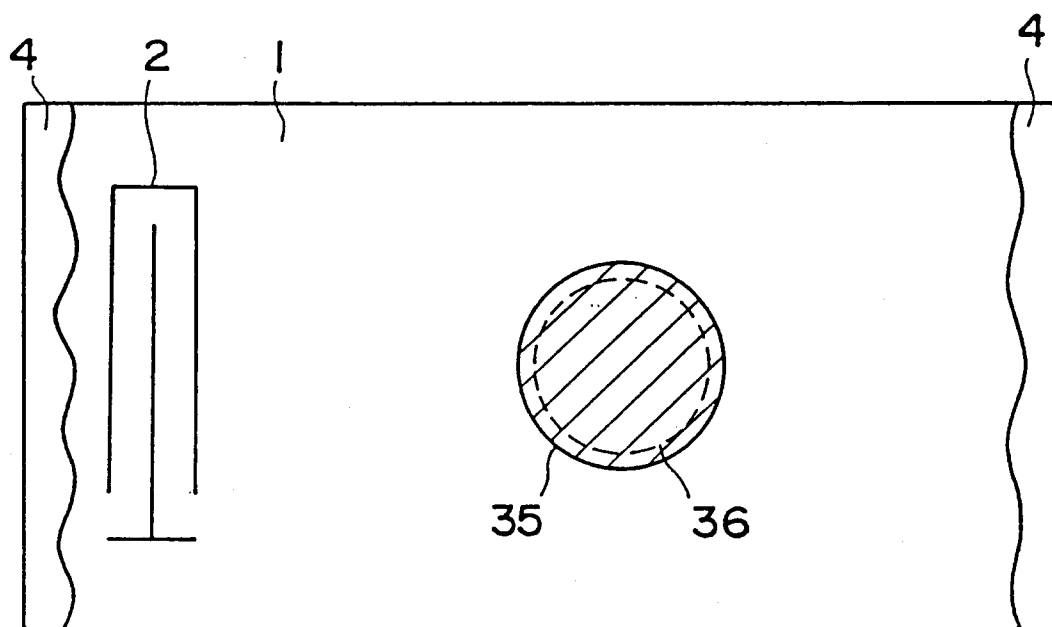
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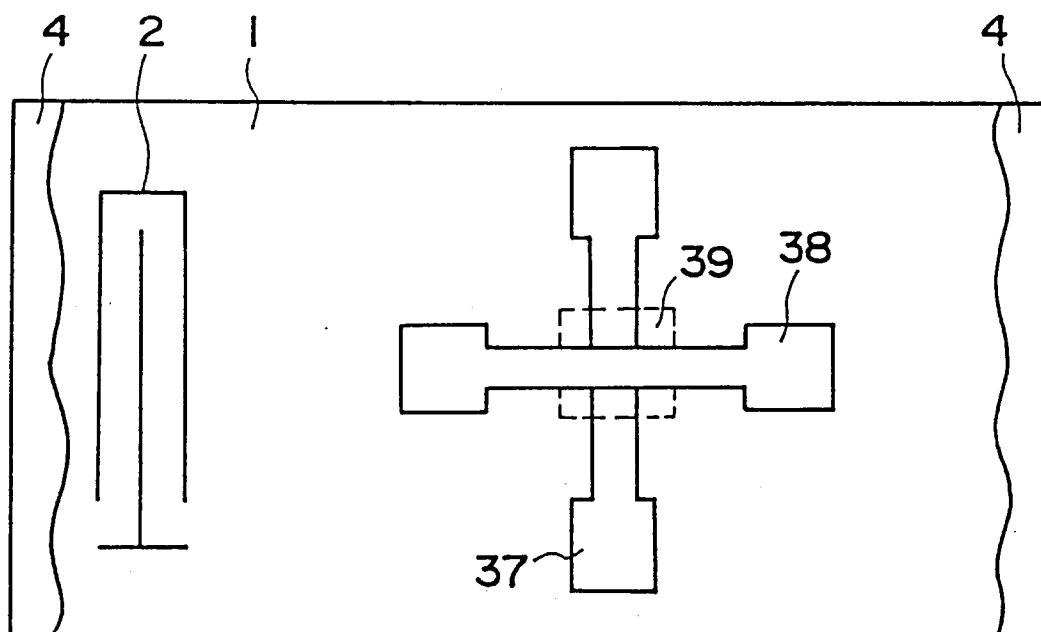
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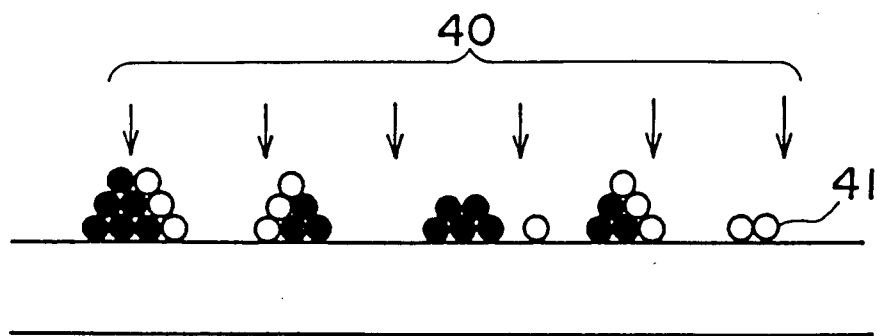
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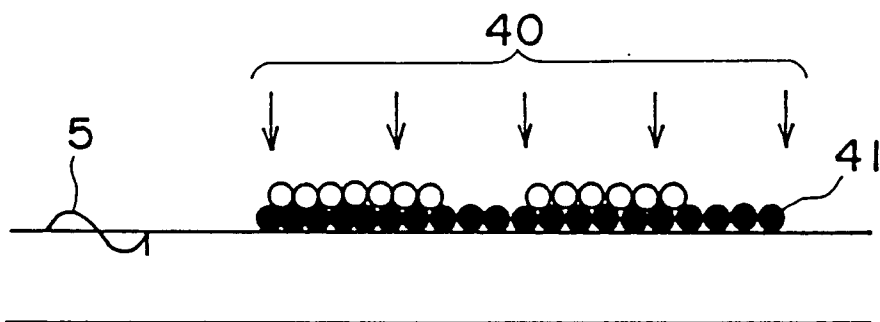
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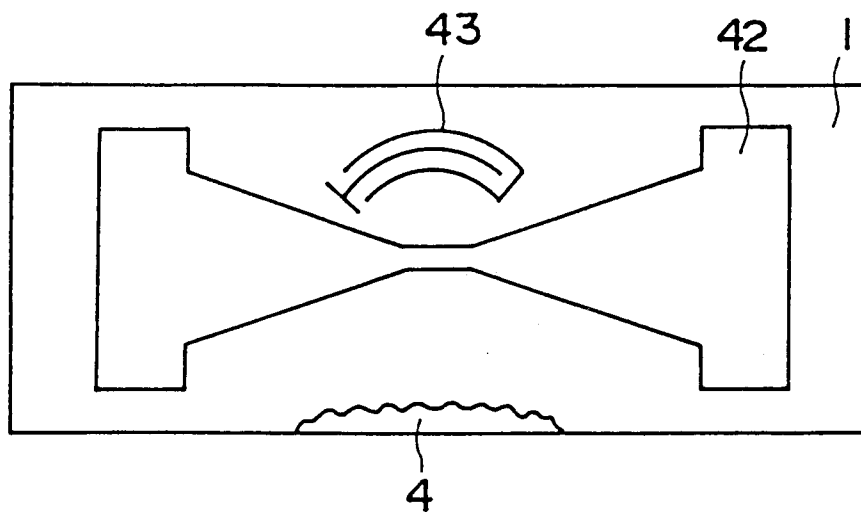
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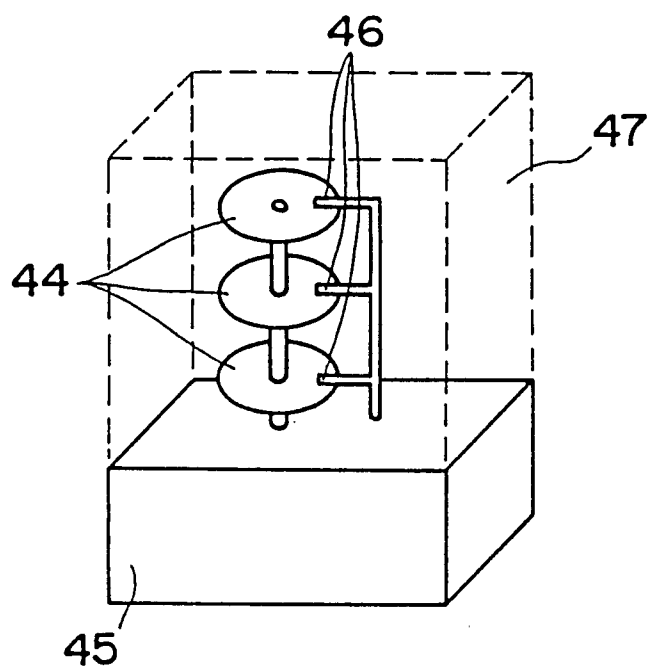
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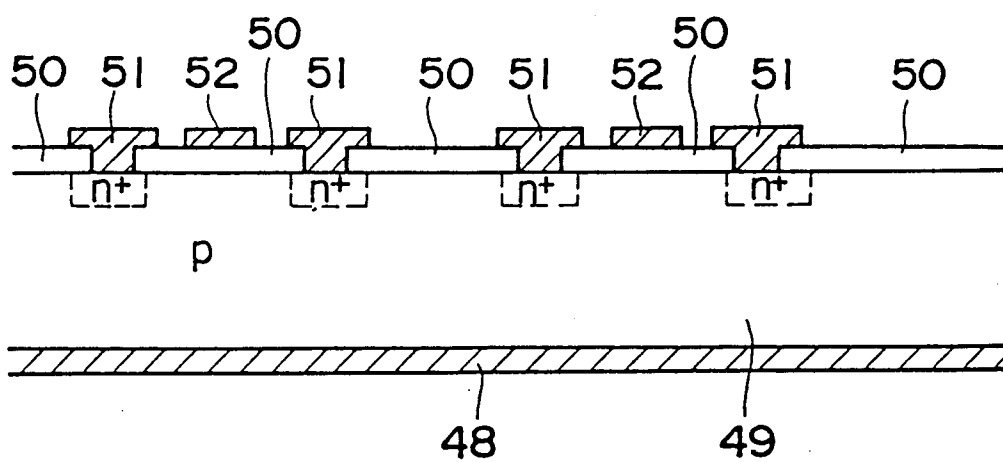
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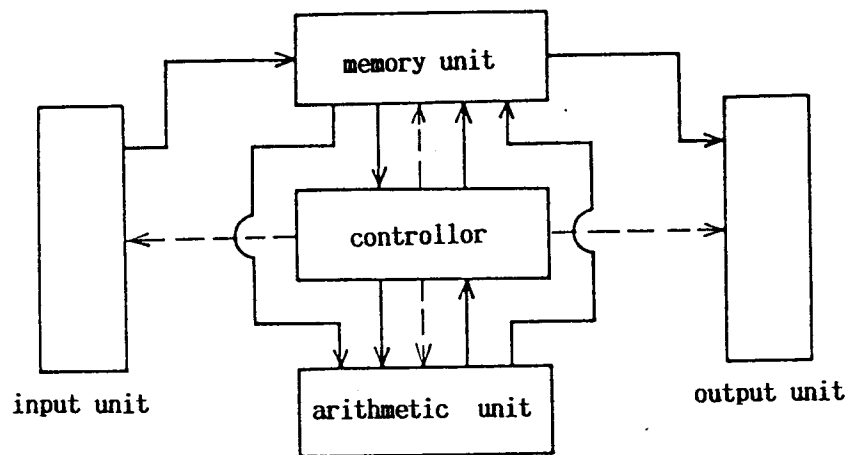
F i g . 2 2



F i g . 2 3



F i g . 2 4



INTERNATIONAL SEARCH REPORT

International Application No PCT/JP90/01507

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int. Cl ⁵ C23C14/22, 16/44, C30B11/00, 23/00, 25/00, G11B5/31, H01L21/203		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
IPC	C23C14/22-14/46, 16/44, C30B11/00-11/14, 23/00-25/22, G11B5/31, H01L21/203	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸		
Jitsuyo Shinan Koho	1926 - 1990	
Kokai Jitsuyo Shinan Koho	1971 - 1990	
III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹		
Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
X	JP, A, 1-261298 (Idemitsu Petrochemical Co., Ltd.), October 18, 1989 (18. 10. 89), (Family: none)	1-2
X	JP, A, 1-317112 (Sumitomo Electric Industries, Ltd.), December 21, 1989 (21. 12. 89), (Family: none)	1-2
Y	JP, A, 1-261298 (Idemitsu Petrochemical Co., Ltd.), October 18, 1989 (18. 10. 89), (Family: none)	3-29
Y	JP, A, 1-317112 (Sumitomo Electric Industries, Ltd.), December 21, 1989 (21. 12. 89), (Family: none)	3-29
X	JP, A, 63-285194 (Toshiba Ceramics Co., Ltd.), November 22, 1988 (22. 11. 88),	30
¹⁰ Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step "Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
January 10, 1991 (01. 10. 91)	January 28, 1991 (28. 01. 91)	
International Searching Authority	Signature of Authorized Officer	
Japanese Patent Office		

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

X	(Family: none) JP, A, 64-79090 (Kawasaki Steel Corp.), March 24, 1989 (24. 03. 89), (Family: none)	30
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V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE ¹

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers , because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claim numbers , because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claim numbers , because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING ²

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

- ☐ The additional search fees were accompanied by applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.